GAS EXPLOSIONS AND THEIR PREVENTION

By G. S. Scott, R. E. Kennedy, and M. G. Zabetakis

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by

G. S. Scott,[1] R. E. Kennedy,[2] and M. G. Zabetakis[3]

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1/ Chemist, Gaseous Explosions Branch, Explosives and Physical Sciences Division, Bureau of Mines, Pittsburgh, Pa.
2/ Scientific Aide, Gaseous Explosions Branch, Explosives and Physical Sciences Division, Bureau of Mines, Pittsburgh, Pa.
3/ Physicist, Gaseous Explosions Branch, Explosives and Physical Sciences Division, Bureau of Mines, Pittsburgh, Pa.

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INTRODUCTION

The Bureau of Mines is engaged in research to assess the hazards associated with the handling, storage, and use of combustible gases, vapors, and liquids encountered in mines and in industry. As a part of this general program, numerous limits of flammability and ignition temperatures are being investigated for a wide variety of combustible materials, and methods are being developed to minimize the explosion hazards of these combustibles.

The Bureau receives numerous requests for information on the explosion hazards of specified combustible mixtures under various conditions of use. This information circular has been prepared to assist those who may have similar requests. Destined primarily for the layman with a limited technical knowledge of the subject, it considers rather briefly the numerous factors that enter into the general problem of gaseous explosions and their prevention.

LIMITS OF FLAMMABILITY

Limits of Flammability of Individual Compounds

If a combustible gas is added continuously to a given quantity of air, the concentration of the gas increases continuously and eventually reaches a value known as the lower limit of flammability.4/ Gas-air mixtures whose concentrations are below the lower limit of flammability are not flammable. With further continuous addition of combustible, a second value, known as the upper limit of flammability, is reached. Gas-air mixtures whose concentrations are above the upper limit of flammability are not flammable. Mixtures whose concentrations lie between the lower and upper limits are flammable, i.e., flame can propagate through the mixture indefinitely once initiated.

If air is added continuously to a combustible gas, the composition of the mixture passes through the same limits of flammability, but in reverse order.

Each combustible gas has its own limits of flammability. Thus, methane has a lower limit of 5 percent and an upper limit of 14 percent by volume in air. Other oxygen-supplying gases may replace air to form flammable mixtures.

4/ The limits of flammability previously referred to as "limits of inflammability," also are sometimes called "explosion limits," "explosive limits," "inflammation limits," etc.

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Such gases as nitrous oxide, nitric oxide, as well as pure oxygen are capable of forming flammable mixtures with combustible gases. The limits of flammability of a given combustible are different in different atmospheres. For example, the limits for methane in oxygen are 5.15 (lower) and 60.5 (upper) percent by volume.

Limits of Flammability of Complex Mixtures

In general, the limits of flammability of a mixture of two or more gases in air may be calculated from their individual limits by means of the mixture rule. Although this rule is applicable to a number of combustible gases, it does not hold for all of them and should be used only for gases known to obey it. The equation to be used follows:5/

$$L = \frac{100}{\frac{p_1}{l_1} + \frac{p_2}{l_2} + \ldots \frac{p_n}{l_n}}$$

where L is the limit of flammability of the mixture to be determined, l_1, l_2 . . . l_n are the corresponding limits of the individual components, and p_1, p_2, . . . p_n are the concentrations of the individual components in the combustible mixture. Limits and concentrations are conveniently expressed in percentages by volume of the combustible in air (or other oxygen-supplying gas).

Example: The limits of flammability in air are 5.0 and 14.0 percent for methane and 4.0 and 74.2 percent for hydrogen. What are the limits in air for a mixture containing 25 percent methane and 75 percent hydrogen?

Solution:

$$\text{Lower limit} = \frac{100}{\frac{25}{5.0} + \frac{75}{4.0}} = 4.21 \text{ percent by volume.}$$

$$\text{Upper limit} = \frac{100}{\frac{25}{14.0} + \frac{75}{74.2}} = 35.76 \text{ percent by volume.}$$

Limits of Flammability of Vapors

A vapor is the gaseous form of a substance that can exist in both the gaseous and liquid forms at ordinary temperatures and pressures.

The vapors of combustible liquids have limits of flammability just as do true gases. However, in the case of vapors, the limits may be expressed

5/ Jones, G. W., Inflammability of Mixed Gases: Bureau of Mines Tech. Paper 450, 1929, 38 pp.

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in terms of temperature as well as concentration. The relationship between temperature limits and concentration limits is illustrated below for styrene.6/

The limits of flammability of styrene vapor in air are 1.10 and 6.10 percent by volume for the lower and upper limits, respectively. Thus, at a barometric pressure of 746 mm. Hg, the lower limit of flammability corresponds to a vapor pressure for styrene of $\frac{746 \times 1.10}{100} = 8.2$ mm. Hg, and the upper limit corresponds to a styrene vapor pressure of $\frac{746 \times 6.10}{100} = 45.5$ mm. Hg. Inspection of the vapor-pressure curve for styrene shows that these two vapor pressures correspond to temperatures of 29.3° and 65.2° C., respectively. Thus, if liquid styrene in contact with air is kept below 29° C., its vapor will not form flammable mixtures with air; similarly, its vapor will not form flammable mixtures with air at temperatures above 66° C., provided the air is saturated with the vapor. If the air is not saturated with styrene vapor, the mixture may contain less than 6.10 percent styrene and may be flammable.

Flash Point

The "flash point" of a liquid corresponds roughly to the lower temperature limit of flammability. It is the temperature at which the liquid gives off enough vapor to form a flammable mixture with air inside a small closed (or open) metal cup. The mixture is tested for flammability by applying a small flame at the top of the cup. The flash-point determination is carried out by an empirical procedure in a standardized apparatus7/ that gives results 5° to 10° C. higher than the actual lower temperature limit of flammability.

The flash-point must not be confused with the ignition temperature, which is the minimum temperature to which a combustible vapor-air mixture must be raised in order to ignite spontaneously (i.e., without other outside assistance, such as the application of flame, spark, heated wire, etc.).

Nonuniform Mixtures

The average composition of a confined gaseous mixture is not necessarily an indication of its safety, unless the gases are well mixed. For example, if 4 cubic feet of methane is added to 96 cubic feet of air in a closed container, the over-all composition is 4 percent methane, which is below the lower limit of flammability and therefore theoretically safe. However, if the methane (whose density is half that of air) is introduced slowly at the top of the container, so that little mixing takes place, there will be a zone between the methane and the air that will be in the flammable range. This zone will persist until diffusion or agitation renders the mixture uniform.

Factor of Safety

The limits of flammability of numerous gases and vapors have been published.8/ These values were determined in the laboratory and are therefore

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6/ Jones, G. W., Scott, G. S., and Miller, W. E., Limits of Inflammability and Ignition Temperature of Styrene in Air: Bureau of Mines Rept. of Investigations 3630, 1942, 5 pp.

7/ A.S.T.M. Serial D56-21.

8/ Coward, H. F., and Jones, G. W., Limits of Inflammability of Gases and Vapors: Bureau of Mines Bull. 279, 1939, 146 pp. Revision in press as Bull. 503.

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somewhat dependent on the conditions of the test, such as direction of flame propagation (upward, downward, horizontal, radial), size of container, ignition source, etc. It is therefore advisable to use a factor of safety in applying such data.

Effect of Temperature on the Limits of Flammability

At elevated temperatures, the limits of flammability are wider than they are at ordinary temperatures. As the temperature rises, the lower limit drops and the upper limit rises.

An investigation of 19 different commercial solvents indicated that a temperature rise of 100 degrees centigrade lowered the lower limit of flammability 14 to 16 percent.9/

Effect of Pressure on the Limits of Flammability

There is a minimum pressure below which mixtures of a given combustible and air will not explode. With ordinary Ford induction-coil sparks, the minimum pressure for the explosions of methane in air is about 42 mm. Hg; i.e., below 42 mm. Hg, methane has no limits of flammability in air. At 70 mm. Hg, the limits of flammability of methane in air are 4.8 percent (lower limit) and 12.2 percent (upper limit).

Increase in pressure above atmospheric widens the limits. The variation of the limits for natural gas in air with pressure10/ are given in the following table:

Pressure	Limits of flammability, percent by volume	
	Lower	Upper
70 mm. Hg.	4.4	11.2
740 mm. Hg.	4.5	14.2
500 p.s.i.g.	4.4	44.2
3,000 p.s.i.g.	3.15	60.0

GAS EXPLOSIONS IN THE ABSENCE OF AIR

Gases or vapors that absorb heat during their formation liberate the same amount of heat when decomposing. Under certain conditions, the decomposition may take place with explosive violence. For example, dry acetylene can explode under a pressure of 6 p.s.i.g. or more, even in the absence of

9/ Matson, A. F., and Dufour, R. E., The Lower Limit of Flammability and the Autogenous Ignition Temperature of Certain Common Solvent Vapors Encountered in Ovens: Underwriters' Laboratories Bull. of Research 43, 1950, 62 pp.

10/ Jones, G. W., Kennedy, R. E., and Spolan, I., Effect of High Pressures on the Flammability of Natural Gas-Air-Nitrogen Mixtures: Bureau of Mines Rept. of Investigations 4557, 1949, 16 pp.

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air or oxygen.[11] Another example is hydrazine; in the absence of air or oxygen, hydrazine vapor can explode at pressures above about 12 mm. Hg by passage of a suitable spark.[12]

Any gas mixture that can react with evolution of heat is potentially flammable. This may be illustrated by the classic example of a mixture of hydrogen and chlorine, which can combine explosively in sunlight to form hydrochloric acid.

GASEOUS PRODUCTS FROM EXPLOSIONS

The gaseous products formed by explosion of combustible-gas-air mixtures near the upper limit contain large amounts of hydrogen and carbon monoxide.[13] Addition of air to these combustion products can form a second explosive mixture, which may be ignited by small fires resulting from the first explosion, thus causing a second explosion. The gaseous products formed by explosion of combustible-gas-air mixtures near the lower limit consist chiefly of carbon dioxide, water, and unused air. Addition of air to these combustion products cannot form explosive mixtures.

The explosion products of mixtures containing chlorinated or fluorinated hydrocarbons contain hydrochloric acid or hydrofluoric acid, respectively.

PRESSURES CREATED BY EXPLOSIONS

The pressures resulting from gaseous explosions vary with the initial pressure and with the composition of the mixture.

Tests in Laboratory-Scale Equipment

In small-scale laboratory equipment the maximum pressures developed by explosions of mixtures of various combustibles and air are roughly 4 to 10 times the pressure before explosion. When only partly confined or unconfined, the gaseous products of an explosion expand to about 4 to 8 times the original volume.[14] The corresponding temperatures of the gaseous products are of the order of 1,900° to 2,000° C.[15]

The pressure-composition curves for various combustible mixtures show that the pressures developed by explosion of mixtures of a given combustible

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11/ Jones, G. W., Scott, G. S., Kennedy, R. E., and Huff, W. J., Explosions in Medium Pressure Acetylene Generators: Bureau of Mines Rept. of Investigations 3755, 1944, 20 pp.

12/ Scott, F. E., Burns, J. J., and Lewis, B., Explosive Properties of Hydrazine: Bureau of Mines Rept. of Investigations 4460, 1949, 18 pp.

13/ Payman, W., and Wheeler, R. V., Flame Speeds and Their Calculation. VI. The Combustion of Complex Gaseous Mixtures. The Products of Combustion: Fuel, vol. 8, 1929, pp. 157-162.

14/ Burgess, M. J., Firedamp Explosions: The Projection of Flame, Part II: S.M.R.B. Paper 42, 1928, 8 pp. (H. M. Stationery Office, London).

15/ Jones, G. W., Lewis, B., Friauf, J. B., and Perrott, G. St. J., Flame Temperatures of Hydrocarbon Gases: Jour. Am. Chem. Soc., vol. 53, 1931, pp. 869-883.

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in air decrease as the composition of the mixture approaches either limit of flammability,16/ the maximum pressure lying in the region between these limits. Figure 1 shows such a curve for methane-air mixtures. The maximum pressure is 109 p.s.i.g. (123.7 p.s.i.a.), corresponding to 10.2 percent methane. This is 8.4 times the initial pressure (atmospheric). It will be noted that the explosion pressure curve decreases as the methane content of the mixture decreases below 10.2 percent and stops abruptly at 31 p.s.i.g. at the lower limit of flammability. The curve also decreases as the methane content of the mixture rises above 10.2 percent, terminating abruptly at 42 p.s.i.g. at the upper limit of flammability. These data were obtained in a 4-liter spherical bomb. The pressures developed in a similar apparatus by explosions of gases other than methane in air may be somewhat greater (or somewhat less), depending on the maximum temperature attained and the volume changes due to reactions.

By modifying the geometry of the apparatus and the location of the ignition point,17/ pressures up to 200 p.s.i.g. have been obtained from methane-air explosions.

In a 4-inch tubular steel bomb 38 inches long and closed at both ends, a suitable mixture of trichloroethylene and air can be exploded by passing a strong electric spark, with a resulting pressure rise up to about 40 p.s.i.g. However, no mixture of trichloroethylene and air will explode in a 1-inch by 12-inch open vertical glass tube with a similar ignition source. Under these conditions enough oxygen must be added to the mixture to make the total oxygen content 26 percent by volume before the mixture will explode.

Tests in Large-Scale Equipment

With turbulent flow through a 4-inch steel pipe line, the explosion of a natural gas-air mixture raised the pressure from about atmospheric to approximately 2,000 p.s.i. at a point 50 feet from the ignition source.18/

IGNITION OF FLAMMABLE MIXTURES

Under the ordinary conditions existing in homes and in industry, it is difficult to insure the complete absence of all sources of ignition, such as open flames, static sparks, inductive sparks, electric arcs, hot wires, compression, shock, friction, heated surfaces, and hot flying particles.

Energy Required for Ignition

When an ignition source of sufficient energy comes in contact with an explosive gas mixture, the mixture explodes. The energy required to ignite an explosive mixture may be very small. For example, certain combustible

16/ Maxwell, G. B., and Wheeler, R. V., The Inflammation of Mixtures of the Paraffins and Air in a Closed Spherical Vessel: Jour. Chem. Soc., 1927, pp. 2069-2080.

17/ Grice, C. S. W., and Wheeler, R. V., Firedamp Explosions Within Closed Vessels. Pressure Piling: S.M.R.B. Paper 49, 1929, 26 pp. (H. M. Stationery Office, London).

18/ Henderson, E., Combustible Gas Mixture in Pipe Lines: 1941 Annual Proceedings of the Pacific Coast Gas Association.

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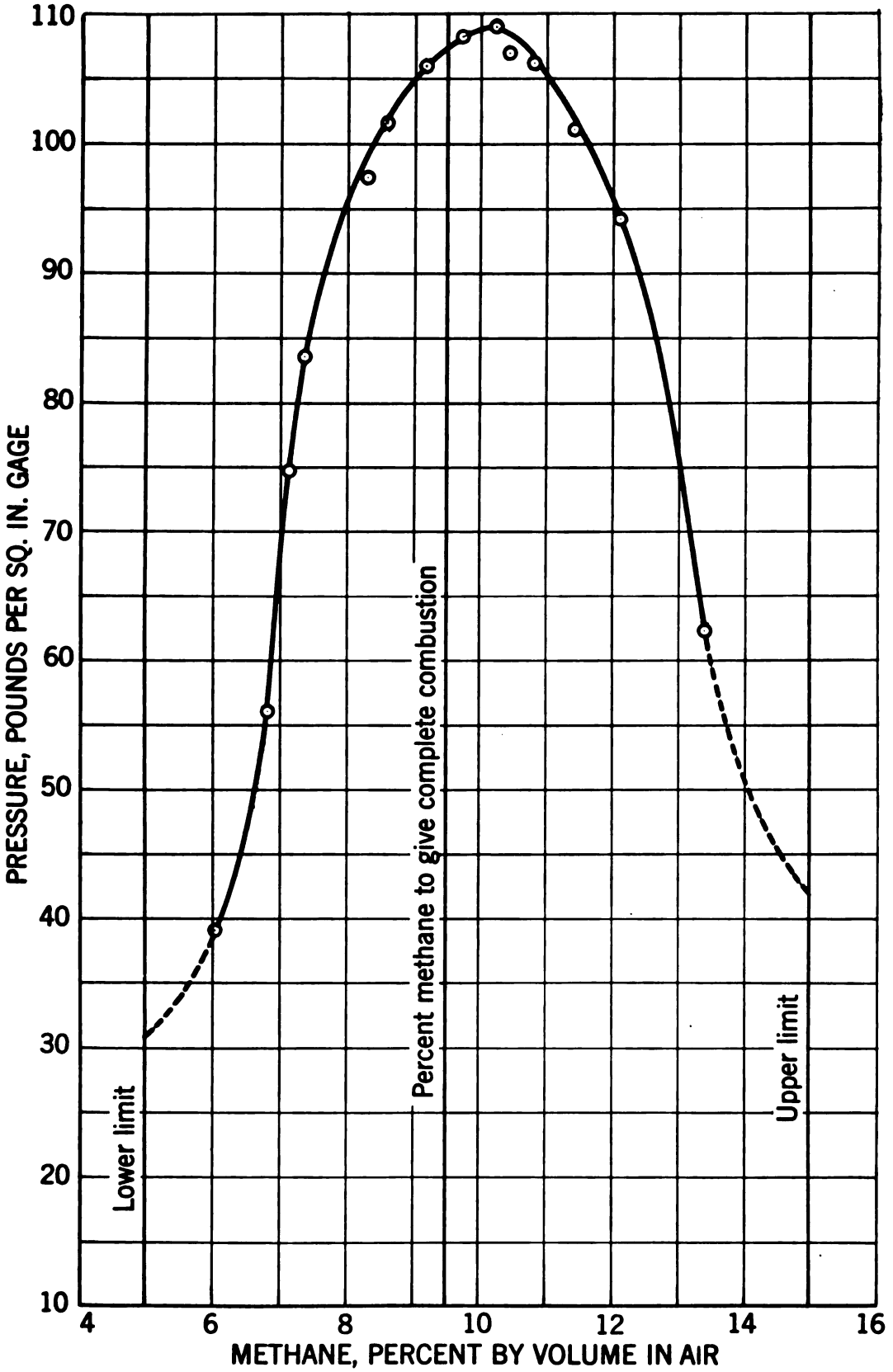

Figure 1. - Effect of composition on pressures developed in methane-air explosions.

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gas-air mixtures can be exploded with static sparks whose energy is as low as two-tenths of a millijoule. This is a thousand times less energy than that liberated by the combustion of the smallest particle of coal that can be weighed on a sensitive analytical balance.

It has been demonstrated[19] that when the human body is electrically charged to 10,000 volts, the weak static spark discharge between the finger and a metal cup of petroleum ether is sufficient to ignite the vapor rising from the cup.

Ignition Temperature

The temperature at which an explosive mixture ignites can only be defined with respect to the system in which the determination is made. Thus, different "ignition" temperatures are obtained in flow systems, static systems, in vessels of different materials, etc.

When an explosive mixture is introduced into a chamber whose temperature is equal to or above the minimum ignition temperature of the mixture, the mixture explodes after a short period of time. This interval is known as the "induction period," the "lag on ignition," or simply the "lag." It is different for different mixtures and generally increases as temperature decreases, reaching its maximum at the minimum ignition temperature.[20]

Factors That Influence Ignition Temperatures

Factors that influence the rate of gas-phase reactions, such as the concentrations of the components, the volume of the container, the surface material, etc., also effect the ignition temperature. For example, in a 15 cc. quartz vessel, a mixture of 5 percent methane and 95 percent air explodes at 740° C., whereas a mixture containing 15 percent methane must be heated to 800° C.[21] In a 440 cc. quartz vessel, the 5 percent mixture ignites at 635° C.[22] In some instances, surface influences are very great. Thus, hydrazine vapor in oxygen ignites at 204° C. in a pyrex glass flask. However, if the bottom of the flask is lined with platinum foil, the same mixture ignites at 30° C. In contact with ferric oxide, hydrazine vapor ignites even at subzero temperatures.[23]

The ignition temperatures of combustible gases in oxygen are usually lower than those in air.

19/ By Paul Guest, in a series of tests conducted at the Pittsburgh Station, Bureau of Mines.

20/ Naylor, C. A., and Wheeler, R. V., The Ignition of Gases. Part VI. Ignition by a Heated Surface. Mixtures of Methane with Oxygen and Nitrogen or Helium: Jour. Chem. Soc., 1931, pp. 2456-2467.

21/ Taffanel, J., and LeFloch, C., (On the Combustion of Gaseous Mixtures and the Inflammation Temperature): Compt. rend., vol. 157, 1913, pp. 469-471.

22/ See footnote 20.

23/ See footnote 12.

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An increase in pressure generally lowers the minimum ignition temperature of an explosive gas mixture. For example, methane in air ignites at 380° C. when adiabatically compressed to 35 atmospheres.24/

Wires or bars suspended in a confined explosive gas mixture at laboratory temperature must be heated to temperatures considerably above the usual ignition temperatures before the mixture ignites. For example, a nickel bar (0.50 by 0.040 by 4.5 inches) suspended in a 4.5-cubic foot box containing 7 percent methane in air at laboratory temperature had to be heated to 1,077° C. before ignition occurred.25/

Mixtures consisting of 5 to 15 percent ether in air have been ignited by the shock produced by suddenly admitting the mixture into an evacuated glass tube 7.5 cm. in diameter and 60 cm. long. Before introduction of the mixture, the temperature of the tube was 16.5° C., and the pressure of the entering gas mixture was less than one-half atmosphere.26/

Data on Ignition Temperatures

Minimum ignition temperatures of 172 combustibles have been published.27/

PREVENTION OF EXPLOSIONS

Elimination of Ignition Sources

Although the complete elimination of all ignition sources is extremely difficult, certain types of sources can be eliminated. Static sparks often can be reduced to impotency either by grounding the materials that accumulate the charges that produce these sparks, or by keeping all such materials at the same potential.

Flameproof electrical equipment, such as sealed lights, etc., may be used in explosive atmospheres but become a hazard if broken or defective. (See also page 11.)

Other potential ignition sources can be eliminated by careful management. For example, compressed gases should not be stored in a room with open flames (e.g. pilot lights).

24/ Coward, H. F., and Wheeler, R. V., The Ignition of Firedamp: S.M.R.B. Paper 53, 1929, 40 pp. (H. M. Stationery Office, London.)

25/ Guest, P. G., Ignition of Natural Gas - Air Mixtures by Heated Surfaces: Bureau of Mines Tech. Paper 475, 1930, 59 pp.

26/ White, A. G., and Price, T. W., The Ignition of Ether-Alcohol-Air and Acetone-Air Mixtures in Contact with Heated Surfaces: Jour. Chem. Soc., 1919, pp. 1462-1505.

27/ Scott, G. S., Jones, G. W., and Scott, F. E., Determination of Ignition Temperatures of Combustible Liquids and Gases: Anal. Chem., vol. 20, 1948, pp. 238-241.

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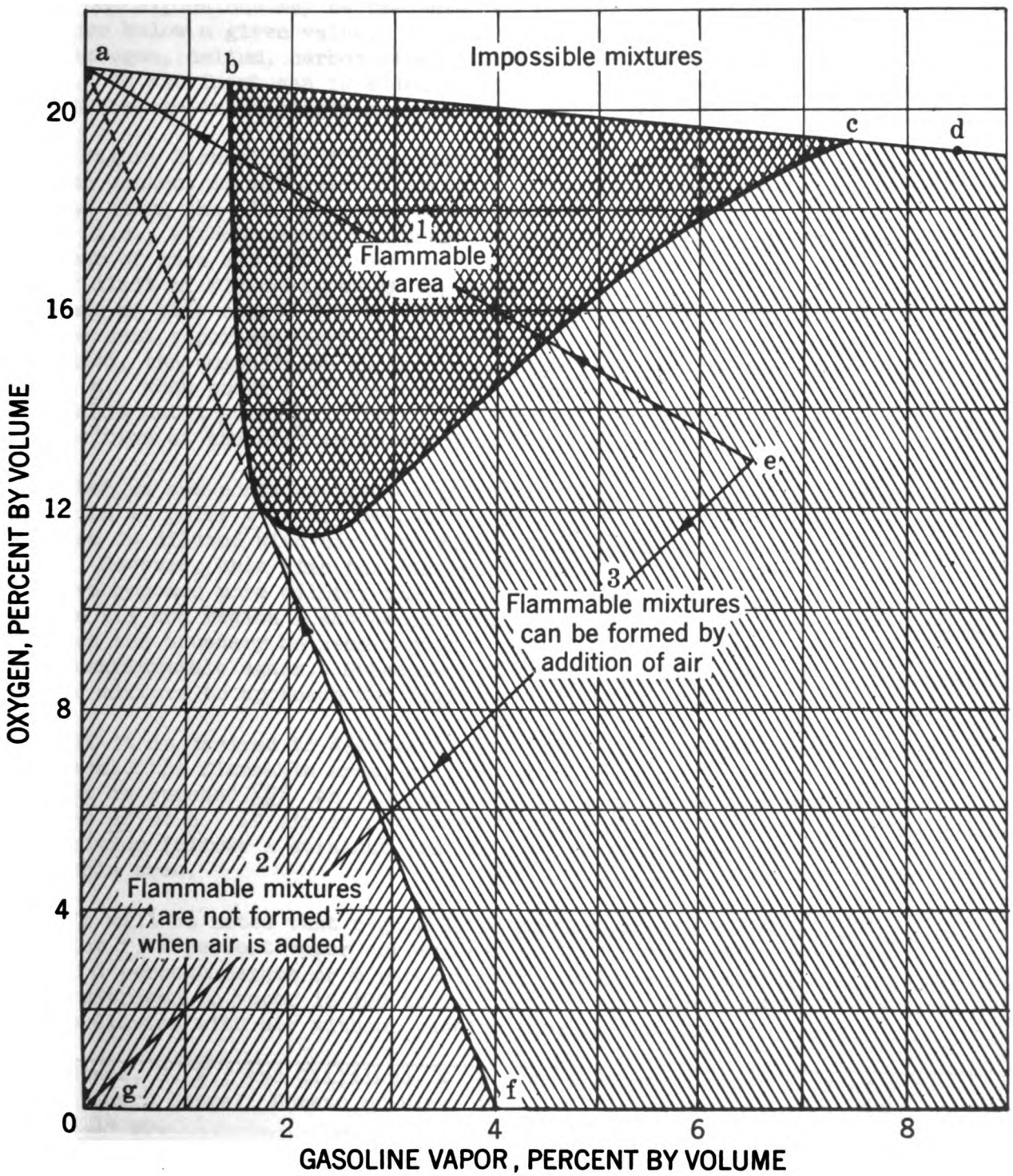

Figure 2. - Effect of added nitrogen on the flammability of gasoline vapor.

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Use of Inert Gases

Gas explosions may be prevented by keeping the oxygen content of the mixture below a given value. This can be done by adding an inert gas (such as nitrogen, helium, carbon dioxide, steam, exhaust gas, etc.) to the mixture. As the inert gas is added to the combustible, the limits of flammability become increasingly narrow and finally disappear altogether.

Figure 2 shows the flammability relations between gasoline vapor and oxygen content in mixtures of gasoline vapor, air, and added nitrogen.[28] Points along the line abcd represent mixtures of air and gasoline vapor only (i.e., without added nitrogen). Point a corresponds to the oxygen content of pure air (20.93 percent). Point b is the lower and point c the upper limit of flammability of the gasoline vapor in air. To illustrate the use of this chart, let us take point d on line abcd. This mixture, 8.5 percent vapor and 19.1 percent oxygen, is above the upper limit. If air is added, the composition changes along the line abcd in the direction of point a. When point c is reached, the mixture becomes flammable and remains flammable until point b is reached. Further addition of air will cause the composition of the mixture to approach the limiting value at a.

Let us now consider point e in the nonflammable region III. The composition at point e is 6.5 percent vapor and 13.0 percent oxygen. If this mixture is diluted with air, the composition again changes along a straight line. However, this time the line goes from point e to point a. As the mixture becomes more dilute, the composition crosses the boundary between region III and region I and becomes flammable; it remains flammable until it crosses the boundary between region I and region II, after which it will become nonflammable again. Subsequent dilution simply causes the composition of the mixture to approach the limiting value at a.

If it is desired to dissipate the mixture at e in air and at the same time avoid the flammable area, nitrogen must be added to the mixture until line af is reached.[29] As it approaches the origin, the composition line crosses af at h. If air is now added to the mixture (at composition h), the composition follows a straight line to a without passing through the flammable area.

It will be noted that region II is bounded on one side by line af. At point f, 4 percent vapor corresponds to 100 percent added nitrogen (i.e., 0 percent oxygen or 0 percent air). This means that if the ratio of added nitrogen to vapor is 100 to 4 (i.e., 25 to 1) or greater, the mixture can be diluted with air without passing through the flammable area.

28/ Jones, G. W., and Gilliland, W. R., Extinction of Gasoline Flames by Inert Gases: Bureau of Mines Rept. of Investigations 3871, 1946, 14 pp.

29/ The addition of oxygen-free nitrogen would cause the composition of the mixture to approach the origin, i.e., 0 percent vapor and 0 percent oxygen.

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The gasoline vapor can also be rendered nonexplosive in air by adding enough liquid carbon tetrachloride to the liquid gasoline for the carbon tetrachloride vapor to make the gasoline vapor nonflammable in air.30/

Inert gases and vapors do not all have the same flame-quenching power. Carbon tetrachloride, for example, has several times the quenching power of nitrogen.

Temperature Control of Liquids

Explosions in vapor-air mixtures may be prevented by keeping the temperature of the liquid outside the flammable range. (See example on pages 2 and 3.)

Substitution of Nonflammable Liquids

Vapor-air explosions may be prevented by substituting nonflammable liquids for flammable liquids when feasible. Thus, halogenated hydrocarbons31/ are used quite extensively as solvents at present; these compounds are not always nonflammable, their flammability depending on the degree of halogenation. For example, methane, which consists of 1 atom of carbon and 4 atoms of hydrogen, is flammable in air in certain concentrations. If 1 atom of chlorine is substituted for 1 atom of hydrogen in the molecule, methyl chloride is obtained, which also is flammable in air. If two chlorine atoms are substituted for two hydrogen atoms, methylene chloride is obtained. This is not flammable in air in an open tube, but is flammable in air enriched by a few percent of oxygen. Substitution of three atoms of chlorine for three atoms of hydrogen yields chloroform, which is nonflammable even in oxygen; and carbon tetrachloride, formed by substituting chlorine for all four hydrogen atoms, is a strong flame quencher.

Ventilation

The formation of explosive mixtures may be prevented by adequate ventilation. For example, leakage of natural gas under cellarless buildings can form explosive mixtures if the space under the building is not ventilated adequately.

Warning Agents

A very odorous compound, such as ethyl mercaptan, may be added to odorless combustible gases to warn of any leakage.32/

30/ Jones, G. W., and Kennedy, R. E., The Explosion and Fire Hazards of Hydrocarbon-Carbon Tetrachloride Mixtures: Bureau of Mines Inf. Circ. 6805, 1934, 8 pp.

31/ Before using halogenated compounds, it is advisable to determine their toxicity and to provide the necessary protection against toxic effects.

32/ Fieldner, A. C., Sayers, R. R., Yant, W. P., Katz, S. H., Shohan, J. B., and Leitch, R. D., Warning Agents for Fuel Gases: Bureau of Mines Monograph 4, 1931, 177 pp.

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MINIMIZING EXPLOSION DAMAGE

Flame Speed and Detonation

After a flammable mixture has ignited, the flame travels initially at a speed which depends upon a number of conditions such as mixture composition, turbulence, temperature, pressure, time from ignition, obstructions, releases, etc. Within certain mixture compositions and under certain other not-too-well-understood conditions, ordinary flames may undergo transition to detonation, which is a flame traveling at speeds well above the velocity of sound.

One of the fastest gas detonations known occurs in a mixture of about 89 percent hydrogen and 11 percent oxygen. When ignited at atmospheric pressure this mixture has a flame speed of over two miles per second.

Flame Arresters

Gaseous explosions sometimes can be localized by means of flame arresters. A flame arrester is a device containing perforated plates, slots, small tubes, packed solids, steel wool, glass wool, etc. It is designed to permit the gas to flow through it and at the same time to act as a barrier to flame. Flame arresters have been developed for stopping the travel at ordinary flame speeds, but to date it has been found difficult if not impossible to stop detonations by these means. Flame arresters should be inspected regularly for corrosion and dirt.

Flameproof Electrical Equipment

Flameproof electrical equipment is designed to prevent the flame of an explosive mixture, which ignites inside the equipment, from propagating to the region outside of the equipment, or to prevent an explosive mixture from coming into contact with an ignition source inside the equipment. Electrical mining equipment is tested regularly to determine its ability to meet certain flameproofing requirements.

Rupture Diaphragms

Rupture diaphragms, rupture discs, or relief diaphragms are thin metallic discs that are substituted for a small part of the wall of a containing vessel. These discs are designed to burst at a given pressure33/ that is less than the bursting pressure of the vessel, thus preserving the vessel itself. Rupture discs afford little protection against flames in high-speed or turbulent-flow mixtures.

Mixing Combustible Gases

Addition of stable gases to an unstable gas may decrease the explosive hazard of the latter. For example, acetylene, which can be exploded in the

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33/ Murphy, T. S., Rupture Diaphragms. Calculations, Characteristics, and Uses: Chem. and Met. Eng., November 1944, pp. 108-112, and December 1944, pp. 99-103.

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absence of air or oxygen at pressures above 6 p.s.i.g. requires much higher pressures for explosion in the absence of air or oxygen when mixed with certain other more stable combustible gases, such as methane, ethane, propane, etc.[34]

Forced Ventilation

Forced ventilation (fans, blowers, etc.) may be used to dissipate explosive mixtures near their source. For example, an explosive mixture of hydrogen and oxygen formed during an electrolytic process may be diluted quickly to concentrations below the lower limit of flammability by rapid addition of a sufficient supply of air. In this way a possible explosion is confined to the gas within the cell.

Segregation of Hazardous Operations

Another means of minimizing explosion damage is the segregation of hazardous operations and hazardous materials. Buildings in which hazardous operations are performed or dangerous materials are stored should be situated at a sufficient distance from other centers of activity.

Alarm Systems

Gas analysis offers a method of determining whether a given atmosphere is flammable or not.

Portable indicators are now available commercially. These instruments are quite simple to operate and are calibrated for a given combustible or group of combustibles, in percentages of the lower limit of flammability.

Larger stationary gas indicators, alarms, and recorders that may be located at points remote from the atmosphere being tested also are available.

SOURCES OF INFORMATION ON GAS EXPLOSIONS

Certain engineering handbooks now include information on limits of flammability and ignition temperatures.

The bibliography in Bulletin 279[35] contains an extensive list of publications relating to the flammability of gases and vapors.

Pamphlets on the safe handling of certain gases and liquids may be obtained from the National Safety Council, 20 North Wacker Drive, Chicago, Ill.; the National Board of Fire Underwriters, 85 John Street, New York City; the Compressed Gas Association, 11 West 42d Street, New York City; and the Manufacturing Chemists' Association, 608 Woodward Building, Washington 5, D. C.

34/ Jones, G. W., Kennedy, R. E., and Spolan, I., Effect of Hydrocarbons and Other Gases Upon the Explosibility of Acetylene: Bureau of Mines Rept. of Investigations 4196, 1948, 8 pp.

35/ See footnote 8.

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The National Fire Protection Association, 60 Batterymarch Street, Boston, Mass., publishes a Handbook of Fire Protection, which includes information on hazardous operations. This association also publishes a list of common hazardous chemicals in cooperation with the American Chemical Society.

The Underwriters' Laboratories, Inc., 207 East Ohio Street, Chicago, Ill., issue pamphlets from time to time, describing the nature of the hazards involved in various operations.

A discussion of the use of inert atmospheres and detailed directions for purging commercial equipment of flammable gases and vapors are given in "Gaseous Fuels."36/

A book covering petroleum and related industries appeared in 1950.37/

Information on the shipping of potentially explosive materials may be obtained from W. S. Topping, 30 Vesey Street, New York, N. Y.38/

36/ American Gas Association, Gaseous Fuels: 1948, pp. 231-268.
37/ Armistead, George, Jr., Safety in Petroleum Refining and Related Industries: John G. Simmonds & Co., New York, 1950, 416 pp.
38/ Interstate Commerce Commission Regulations for Transportation of Explosives and other Dangerous Articles by Freight, Freight Tariff 4, 1941.

Interior - Bureau of Mines, Pittsburgh, Pa.

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